"To protect your rivers, protect your mountains"
Emperor Yu of China, 1600 BC

New River Gorge
photo by Frank Sellers

Vital Signs Monitoring Program

Phase II Report

Eastern Rivers and Mountains Network

US Department of the Interior
National Park Service

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PREFACE

In 2003, nine national park service units in Pennsylvania, New York, New Jersey, and West Virginia, collectively referred to as the Eastern Rivers and Mountains Network, began the process of developing and implementing a long-term ecological monitoring program known as the vital signs monitoring program. Establishment of the monitoring portion of the ERMN program has been directed by national-level guidance and culminates in the publication of a peer-reviewed monitoring plan. The monitoring plan for each network is to be written in three phases, corresponding to three phases of program development, over a period of roughly three to four years. The first report, the Phase I report, is a preliminary look at the initial chapters of the monitoring plan and describes the parks within the network and the resources therein. The Phase II report builds on the Phase I report by outlining an initial list of prioritized vital signs chosen by the network. Finally, the Phase III report provides the implementation and staffing plans for the program.

This document is the Phase II report for the Eastern Rivers and Mountains Network.

The overall process that this network has followed in planning, designing, and implementing its vital signs monitoring program, as well as additional information on the National Inventory and Monitoring Program, is described in more detail at the NPS Inventory & Monitoring website (http://science.nature.nps.gov/im/index.htm).

This report, along with all appendices and other supporting documents as well as additional information on the Eastern Rivers and Mountains Network is available from network's website (http://www1.nature.nps.gov/im/units/ermn/index.htm).

"To protect your rivers, protect your mountains"
Emperor Yu of China, 1600 BC

New River Gorge
photo by Frank Sellers

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EXECUTIVE SUMMARY

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations" as mandated by the National Park Service Organic Act of 1916. National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources to inform the management decision-making process. This type of understanding is also necessary to effectively work with other government agencies and the public for the benefit of park resources.

To address this need, NPS has implemented a strategy known as “vital signs monitoring” to develop scientifically sound information on the status and long-term trends of park ecosystems and to determine how well current management practices are sustaining those ecosystems.

National parks have been grouped into 32 vital signs networks linked by geographic similarities, common natural resources, and resource protection challenges. The network approach facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. The approach also will provide parks with a “minimum infrastructure” to initiate natural resource monitoring.

One of these networks, the Eastern Rivers and Mountains Network (ERMN), includes nine park units in Pennsylvania, New York, New Jersey, and West Virginia. The ERMN parks range in size from approximately 66 to 30,000 hectares and generally consist of a mosaic of forested hillsides and floodplains, streams and rivers, tallus slopes and cliffs, vernal pools and wetlands, open fields and agriculture. The ERMN parks formed around rivers contain some of the most significant water resources and water-based recreational activities in the National Park system.

Dominant natural resource management issues in the ERMN include maintaining and improving water quality of large rivers and tributary streams and maintaining the integrity of a diverse set of terrestrial ecosystems. The world class waters of the ERMN support exceptional water-based recreation activities and globally significant natural resources that are threatened by acid mine drainage, fecal coliform bacteria, and headwater urbanization, among other threats. Similarly, the biologically diverse suite of terrestrial systems is threatened by invasive species, atmospheric deposition and ozone, and urbanization surrounding parks, among other threats.

Initial planning efforts began in 2002 when the ERMN received funding to conduct baseline inventories in its parks to support early development of the monitoring plan. In the fall of 2003, Matthew Marshall was hired as Network Coordinator and Nathan Piekielek was hired as Network Data Manager to begin, in earnest, the development of the ERMN monitoring program. Both are stationed at the Pennsylvania State University, School of Forest Resources, University Park, Pennsylvania.

The monitoring plan for each network is to be written in three phases, corresponding to three phases of program development, over a period of roughly three to four years. The first report, the Phase I report, is a preliminary look at the initial chapters of the monitoring plan and describes the parks within the network and the resources therein. The Phase II report builds on the Phase I report by outlining an initial list of prioritized vital signs chosen by the network. Finally, the Phase III report provides the implementation and staffing plans for the program. This document is the Phase II report for the Eastern Rivers and Mountains Network.

In the fall of 2002, the first Board of Directors Meeting took place with subsequent meetings to occur annually thereafter. The seven-member Board of Directors consists of five superintendents, one representing each ERMN park unit, the Northeast Region I&M Coordinator, and one of the Northeast Region's Chief Scientists. The Board's role is to ensure program accountability and maintain its relevance to individual park units' needs. A network Science Advisory Committee, chaired by the ERMN Coordinator, has also been organized to assist and oversee program development and ensure scientific quality and integrity.

The ERMN identified four dominant, general ecosystems (large rivers, tributary watersheds, riparian/floodplain communities, and terrestrial ecosystems) for initial conceptual ecological modeling. These models are essential for designing a scientifically credible monitoring strategy and are intended to formalize current understanding of system processes and dynamics, identify linkages of processes across disciplinary boundaries, identify the bounds and scope of the system of interest, and contribute to communication among scientists and program staff, between scientists and managers, and with the general public. These models are simplifications of complex systems that will help the NPS and its partners identify critical indicators, i.e., 'vital signs' of park ecosystems as well serve as the ecological foundation for interpreting monitoring data.

The process for choosing and prioritizing vital signs has been ongoing within the network since the fall of 2003 and has been a multifaceted process of park-level scoping workshops, subject matter expert evaluation, a broad vital signs prioritization workshop, park-level rankings, Science Advisory Committee review (scheduled for fall 2005), and Board of Directors approval (scheduled for fall 2005). Over the last year we have focused the vital signs list and placed it within the conceptual models for the network.

The ERMN identified 37 vital signs that represent a systems approach to our monitoring program. Three vital signs relate to air and climate, three relate to geology and soils, five relate to water, two relate to human use, four relate to ecosystem pattern and processes, and 20 relate to biological integrity. Through the network prioritization process of meetings and ranking exercises, a short list of the highest priority vital signs has been created that the network plans to develop monitoring protocols and implement in the next three to five years.

ACKNOWLEDGMENTS

The development of a successful long-term ecological monitoring program will not be possible without the support of many dedicated individuals. We wish to thank Gary Williams, Steve Fancy, John Gross, and others with the National Inventory & Monitoring (I&M) program for guidance and support. We also wish to generously thank Beth Johnson, Northeast Region I&M Coordinator, for all that she has done for us and the program. The Superintendents, Resource Managers and their staffs at each of the parks deserve special thanks for your invaluable knowledge, help, and guidance—this program would not be possible without you, and, ultimately, is for you and the resources under your stewardship.

The Inventory and Monitoring Program was made possible through the National Park Service Natural Resource Challenge.

CHAPTER 1-- INTRODUCTION AND BACKGROUND

In 1999 the National Park Service (NPS) embarked on a new era of science-based management called the Natural Resource Challenge. An essential component of this program is to characterize and determine trends in the condition of natural resources in national park units. NPS resource monitoring is designed to inform park managers of the condition of water, air, geologic resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. The broad-based, scientific information obtained through monitoring has multiple applications for management decision making, research, education, and promoting public understanding of park resources.

Through the Natural Resource Challenge, 274 of the 388 NPS units have been recognized as natural area parks and are organized into 32 networks (Figure 1.1) to conduct long-term ecological monitoring. Termed the Vital Signs Monitoring Program, these networks compile and synthesize existing information, conduct current inventories of vertebrates and vascular plants, evaluate current monitoring efforts, and draw on expert recommendations to identify the highest priority vital signs to monitor in national parks.

Figure 1.1. Map of the 32 Inventory and Monitoring Program Networks established by the Natural Resource Challenge.

Establishment of the monitoring portion of the program has been directed by national-level guidance (http://science.nature.nps.gov/im/monitor/testindex.htm) and culminates in the publication of a peer-reviewed monitoring plan. The monitoring plan for each network is to be written in three phases, corresponding to three phases of program development, over a period of roughly three to four years. The first report, the Phase I report, is a preliminary look at the initial chapters of the monitoring plan and describes the parks within the network and the resources therein. The Phase II report builds on the Phase I report by outlining an initial list of prioritized vital signs chosen by the network. Finally, the Phase III report provides the implementation and staffing plans for the program.

1.1 Purpose of the Vital Signs Monitoring Program

The general purpose of the Vital Signs Monitoring Program is to provide information to detect, predict, and understand changes in ecosystem resources of primary interest to the park(s) that contain them.. In this section, we provide a general overview of the Eastern Rivers and Mountains Network, review the justification for integrated natural resource monitoring, define "vital signs", and summarize the substantial legal and policy framework in place supporting ecological monitoring on NPS lands.

1.1.1 General Overview of the Eastern Rivers and Mountains Network

The Eastern Rivers and Mountains Network (ERMN), includes nine parks in New York, New Jersey, Pennsylvania, and West Virginia (Figure 1.2) and together encompass roughly 60,000 hectares of land area, 211 miles of river, and more than 425 miles of stream (Table 1.1). The ERMN includes a small segment of the Appalachian Trail, however I&M activities associated with the trail are currently coordinated by the Northeast Temperate Network. The four smallest parks in the network (Table 1.1) were established for the interpretation and preservation of cultural resources including two National Historic Sites, one National Battlefield, and one National Memorial, yet also contain valuable natural resources including rare or regionally important plant and animal species and communities. The remaining five parks were established primarily for the interpretation and preservation of natural resources including Wild and Scenic Rivers designation. The river parks in the ERMN contain some of the most significant water resources and water-based recreational activities in the national park system.

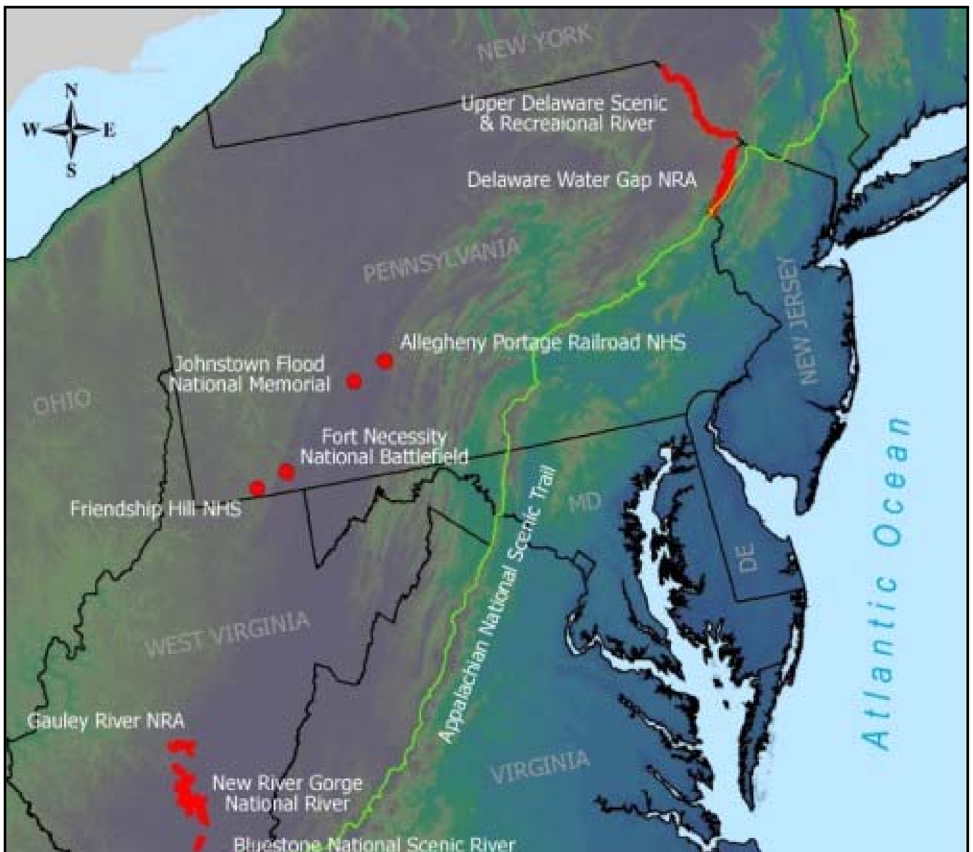


Figure 1.2. Location of Eastern Rivers and Mountains Network Parks

Major habitats range from broad rivers and floodplains to small, ephemeral streams, high mountains to deep gorges, and dry barrens to mesic forests. The broad, gently-rolling hills have rounded, usually dry-oak forested summits with gradually sloping sides of mixed mesophytic forest that are separated by narrow valleys with well drained, rich soils. Many areas are much more rugged with steep gorges, tallus slopes, and cliff faces. The maintenance of many of these habitats is dependent upon natural disturbances such as fire, wind, flooding, landslides, ice storms, insects, and occasionally hurricanes. Ecologically, these natural disturbances have played a large role in determining many of the intricate landscape patterns that characterize the ERMN both spatially and temporally. A long legacy of human uses including agriculture, logging, and mining has also shaped, and continues to influence, contemporary ecological systems from local to landscape scales. An understanding of current and future ecosystem properties must take into account these past land uses.

Table 1.1. Brief overview statistics for Eastern Rivers and Mountain Network parks.

Park Name	Park Code	State(s)	Year Established	Visitors (2003)	Hectares (2003)	Acres (2003)	River Miles	Stream Miles
Allegheny Portage Railroad National Historic Site	ALPO	PA	1964	127,823	505	1,249	---	5.3
Johnstown Flood National Memorial	JOFL	PA	1964	117,179	66	164	---	0.9
Friendship Hill National Historic Site	FRHI	PA	1978	34,558	273	675	---	1.5
Fort Necessity National Battlefield	FONE	PA	1931	93,649	365	902	---	3.7
Upper Delaware Scenic and Recreational River	UPDE	PA/NY	1978	259,713	22,490	55,575	74	147
Delaware Water Gap National Recreation Area (Middle Delaware Scenic and Recreational River)	DEWA	PA/NJ	1965 (1978)	4,616,320	27,191	67,192	40	138
Bluestone National Scenic River	BLUE	WV	1988	50,384	1,744	4,310	13	4.5
Gauley River National Recreation Area	GARI	WV	1988	152,706	4,657	11,507	31	15
New River Gorge National River	NERI	WV	1978	1,121,416	29,214	72,189	53	111

1.1.2 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations" as mandated by the National Park Service Organic Act of 1916. National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with threats such as air and water pollution, or invasive species, originating outside of the park's boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or may be indicators of unwanted influences. Thus, monitoring provides a basis for understanding and identifying meaningful change in natural systems characterized by complexity, variability, and surprises. Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

"**Vital signs**," as defined by the NPS, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate naturally (e.g., on park lands near developed areas where a history of flood and fire control has fundamentally altered natural disturbance regimes), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. Broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and the promotion of public understanding of park resources.

1.1.3 Federal Legislation, Policy and Guidance on Natural Resource Monitoring

National Park managers are directed by federal law and National Park Service policies and guidance to know the status, trends and condition of natural resources under their stewardship in order to fulfill the NPS mission of conserving parks unimpaired. The mission of the National Park Service (National Park Service Organic Act, 1916) is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the*

> *wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*".

Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that *"the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…".*

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*", and to *"… assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

> *"Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions".*

Further, *"The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents;*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources;*

- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals;*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames;*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (2001 NPS Management Policies).*

Refer to "Appendix B – Summary of Laws, Policies and Guidance" for more detail on the substantial framework in place justifying the establishment of the vital signs monitoring program.

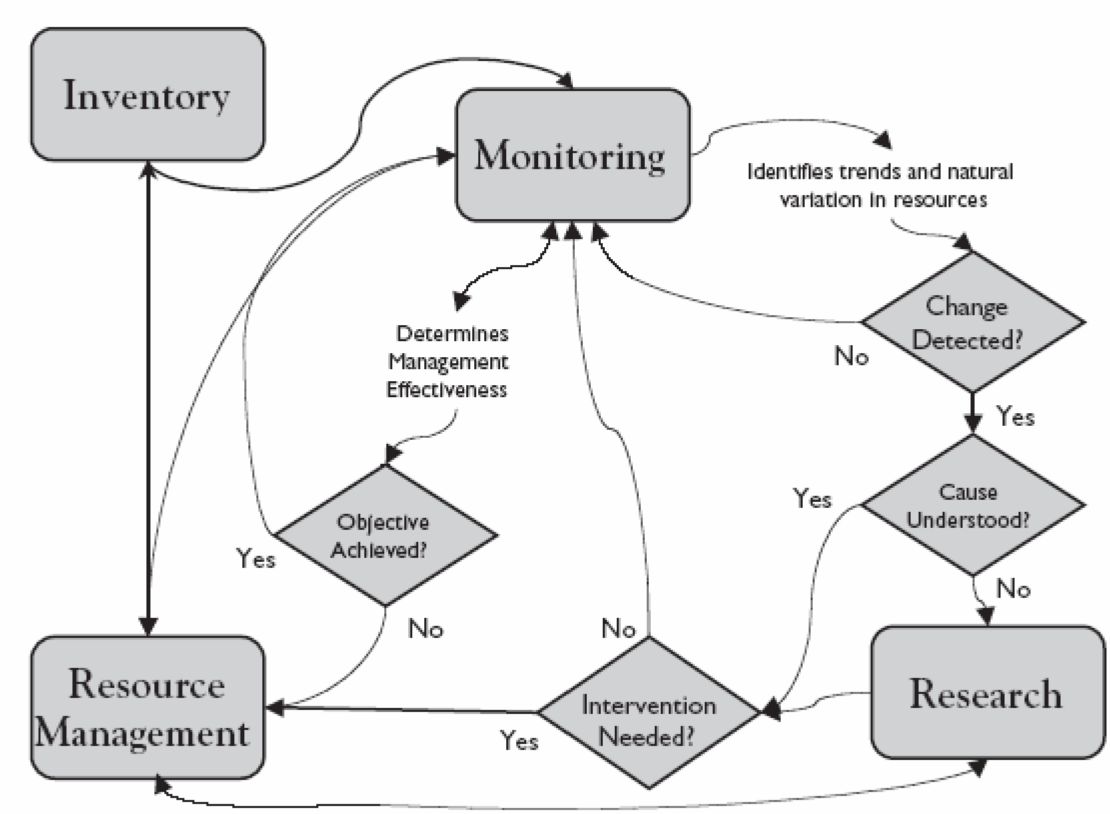
1.2 Natural Resource Monitoring Goals and Strategies

In this section, we first discuss the importance of inventory, monitoring, and research in stewarding natural resources. We then present the servicewide vital signs monitoring program goals and conclude with a conceptual approach for determining what to monitor (further developed in Chapters 2 and 3).

1.2.1 Interrelated Roles of Inventories, Monitoring, and Research

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories, management, and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1.3).

Figure 1.3. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al. 2002).



Natural resource inventories are extensive point-in-time efforts to determine the location or condition of a resource, including the presence, class, distribution, and status of plants, animals, and abiotic components such as water, soils, landforms, and climate. Monitoring differs from inventories by adding the dimension of time; the general purpose of monitoring is to detect changes or trends in a resource. Elzinga et al. (1998) defined monitoring as, “the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.” Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Research is generally defined as the systematic collection of data that produces new knowledge or relationships and usually involves an experimental approach, in which a hypothesis concerning the probable cause of an observation is tested in situations with and without the specified cause. A research design is usually required to determine the cause of changes observed by monitoring. The development of monitoring protocols also involves a research component to determine the appropriate spatial and temporal scale for monitoring.

1.2.2 Servicewide Vital Signs Monitoring Goals

The servicewide goals for vital signs monitoring in the National Park Service are to:

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.

2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.

3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.

4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.

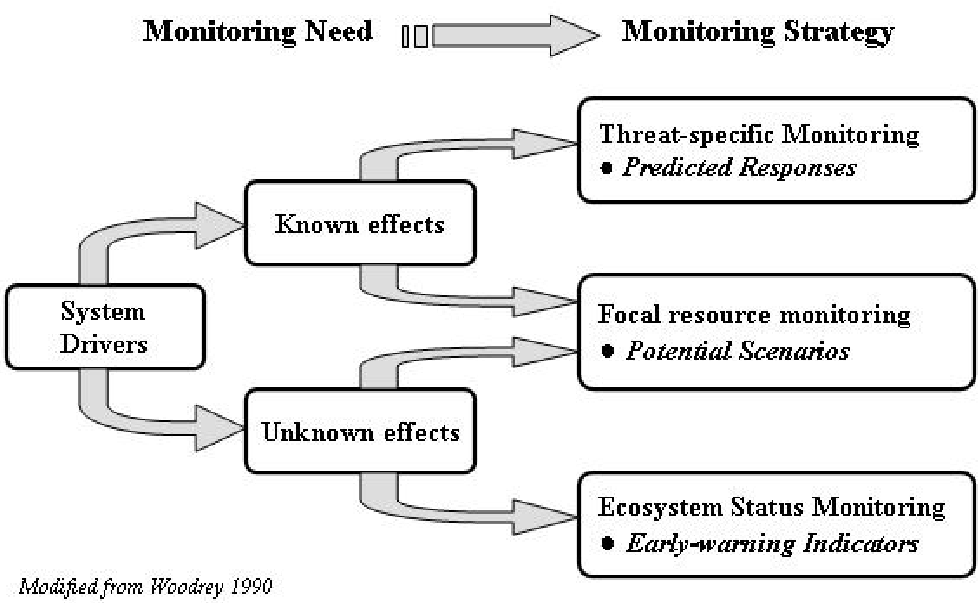
5. Provide a means of measuring progress towards performance goals.

1.2.3 Strategies for Determining What to Monitor

Effective monitoring programs provide information that can be used in multiple ways. The most widely identified application of monitoring information is that of enabling managers to make better-informed management decisions (White and Bratton 1980, Croze 1982, Jones 1986, Davis 1989, Quinn and van Riper 1990). Another use of monitoring information is to document changes primarily for the sake of familiarity with resources (Croze 1982, Halvorson 1984). By gathering data over long periods, correlations between different attributes become apparent, and resource managers gain a better general understanding of the ecosystem. A third use of monitoring information may be to convince others to make decisions benefiting national parks (Johnson and Bratton 1978, Croze 1982). Monitoring sensitive species, invasive species, culturally significant species, or entire communities can provide park managers, stakeholders, and the public with an early warning of the effects of human activities before they are noticed elsewhere (Wiersma 1989, Davis 1989). Finally, a monitoring program can provide basic background information that is needed by park researchers, public information offices, interpreters, and those wanting to know more about the area around them (Johnson and Bratton 1978).

Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley et al. (1993), Woodward et al. (1999), Jenkins et al. (2002) and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program, or alternate taxonomic, integrative, reductionist, or hypothesis- testing monitoring designs (Woodley et al. 1993, Woodward et al. 1999). The approach adopted by ERMN agrees with the assertion that the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches (termed the "hybrid approach" by Noon 2003), while recognizing that the program will not succeed without also considering political issues. A multi-faceted approach for monitoring park resources was adapted, based on both integrated and threat-specific monitoring approaches and building upon concepts presented originally for the Canadian national parks (Figure 1.4.; Woodley et al. 1993).

Figure 1.4. Conceptual approach for selecting Vital Signs.



This system segregates indicators into one or more of four broad categories:

(1) ecosystem drivers that fundamentally affect park ecosystems,
(2) stressors and their ecological effects,
(3) focal resources of parks, and
(4) key properties and processes of ecosystem integrity.

In cases where there is a good understanding of relationships between potential effects and responses by park resources (known effects), monitoring of system drivers, stressors, and effected park resources is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to improve long-term understanding and potential early warning of undesirable changes in park resources.

Natural ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, and hydrologic cycles that have large scale influences on natural systems (see Chapter 2). Trends in ecosystem drivers will have corresponding effects on ecosystem components and may provide early warning of presently unforeseen changes to ecosystems. Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Focal resources, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the National Park Service. Chapter 2 summarizes how we incorporated this approach into our understanding of ecosystem properties while Chapter 3 more fully describes the vital signs selection and prioritization process.

1.3 Natural Resources of the Eastern Rivers and Mountains Network – What is important?

One of the primary tasks in program development was to develop a comprehensive list of significant natural resources for network parks to help generate and support a candidate list of vital signs for monitoring. We first grouped these resources into four categories as they pertain to the enabling legislation of the park, to legal mandates or policy, for other reasons such as regional or global rarity, and as they relate to the 1993 Government Performance and Results Act. Verbal descriptions of each category follow and are also paraphrased and listed in Tables 1.2, 1.3, and 1.4. Source materials for the information below not specifically cited include NPS General Management Plans (NPS 1982a, 1982b), Strategic Plans (NPS 1999), Resource Management Plans for the respective parks (NPS 1993, 1998, 2000, 2002a, 2002b, 2002c) and Purvis and Wilson (2002). We also explicitly discuss the integration of air and water quality monitoring into program development and summarize current park-based monitoring programs. We conclude this section with a summary of the dominant management issues of network parks.

1.3.1 Natural Resources Significant to Enabling Legislation

Four parks in the network (Gauley River National Recreation Area, GARI; New River Gorge National River, NERI; Delaware Water Gap National Recreation Area, DEWA; and Upper Delaware Scenic and Recreational River, UPDE) were established primarily for water-based recreation, and/or to preserve important aquatic, terrestrial and geologic resources (Table 1.2). For example, the enabling legislation for DEWA specifically states that the park unit be established "for the preservation of the scenic, scientific and historic features, contributing to public enjoyment of such lands and water" within the park unit.

Three of the parks (Bluestone National Scenic River, BLUE; UPDE and DEWA) contain river sections that have Wild and Scenic River designation, which contributed wholly or partly to the creation of the park. The October 1978 act, proclaims:

> *… that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.*

The remaining four parks (Allegheny Portage Railroad National Historic Site, ALPO; Johnstown Flood National Memorial, JOFL; Friendship Hill National Historic Site, FRHI; and Fort Necessity National Battlefield, FONE) were established to preserve and interpret cultural resources, although natural resources have since become part of the current management focus. In many cases, changes to the cultural landscape also influences (both positively and negatively) the natural resources of the park. Consequently, attempts to maximize both cultural and natural resource objectives simultaneously are critical.

1.3.2 Natural Resources Significant to Legal Mandates and Policy

Five ERMN parks (DEWA, UPDE, NERI, BLUE and GARI) have at least one species that is Federally threatened or endangered including one bird species (bald eagle, *Haliaeetus leucocephalus*), one mussel species (dwarf wedge mussel, *Alasmidonta heterodon*), one plant species (Virginia spirea, *Spiraea virginiana*), two mammal (Indiana bat, *Myotis sodalis*; and Virginia big-eared bat, *Corynorhinus townsendii virginianus*), and one reptile species (bog turtle, *Clemmys muhlenbergii*). All of the parks have at least one (and in many cases numerous) plant or animal species that are listed on a state endangered or threatened species list (except those in West Virginia, which does not have a state list, but species are ranked according to their state and global rarity). As biological inventories continue throughout the parks, additional rare species may be found. See "Appendix D – Species of Special Concern" for the most current list of federally and state listed, and state and globally rare species found at each park.

Many parks also have surface waters that are designated as high quality or exceptional waters (or similar designation) and receive special protection and/or require that existing beneficial uses are maintained and protected. For DEWA and UPDE, the Delaware River Basin Commission has adopted a Special Protection Designation for the Delaware River and its tributaries designed to prevent degradation in streams and rivers considered to have exceptionally high scenic, recreational, and ecological values. See "Appendix G – Water Quality Summaries" for park-specific water quality summaries and additional information on legal, regulatory and specially designated waters in the ERMN.

Three of the parks in the Network (UPDE, BLUE and DEWA) have National Wild and Scenic Rivers within their boundaries. While this designation does not afford protection from development or use of the river system, the implicit goal is to protect the character and integrity of the river system.

According to mandates within the Clean Water Act, if water quality standards set forth by the Environmental Protection Agency are violated, the waterbody is considered impaired and will be scheduled for Total Maximum Daily Load (TMDL) development. Each state is responsible for monitoring the waterways within their state and development of appropriate remediation. Several of the parks within the network contain waters that are listed on the state's 303(d) list of impaired waterways (see "Appendix G – Water Quality Summaries").

Table 1.2. Significant natural resources summary as they pertain to the enabling legislation of the park, to legal mandates or policy, or for other reasons such as global rarity.

Park	Reason Enabling Legislation	Natural Resources Significant to Legal Mandates/Policy	Natural Resources Significant for Other Reasons
ALPO	Preservation of Allegheny Portage Railroad trace	state listed plant species wetlands migratory birds	species of special concern Blair gap run (good quality stream) forest habitat
JOFL	Commemoration of 1889 Johnstown Flood	state listed plant species wetlands migratory birds state impaired waters	species of special concern wet meadow habitat
FONE	Commemoration of Battle of Fort Necessity	state listed species migratory birds wetlands	species of special concern shrubland habitat high quality streams
FRHI	Preservation of the home of Albert Gallatin	migratory birds wetlands	species of special concern floodplain forest
DEWA	Public outdoor use and Wild and Scenic River designation	Wild and Scenic River federally listed species state listed species special protection waters state impaired waters wetlands migratory birds Appalachian trail	hemlock ecosystems geologic resources globally rare species & communities high quality streams
UPDE	Public outdoor use and Wild and Scenic River designation	Wild and Scenic River federally listed species special protection waters state impaired waters migratory birds	geologic resources globally rare species high quality streams
NERI	Conserve and interpret outstanding natural values and objects; preserve section of free-flowing river	migratory birds state impaired waters American Heritage River	geologic resources globally rare species & communities state rare species large block of mixed mesophytic forest high quality streams
GARI	Preserve scenic, recreational, geological, fish and wildlife resources	federally listed species migratory birds state impaired waters	geologic resources globally rare species state rare species high quality streams
BLUE	Public outdoor use and Wild and Scenic River designation	federally listed species Wild and Scenic River state impaired waters migratory birds	globally rare species state rare species high quality streams

1.3.3 Natural Resources Significant for Other Reasons

Many of the parks contain regionally and globally significant, and/or rare natural resources (Table 1.3 and "Appendix D – Species of Special Concern"). For example, the globally significant natural resources at NERI include large, apparently stable populations of Allegheny woodrats (*Neotoma magister*), the rare Appalachian flatrock/riverscour plant community, and one of the largest remaining unfragmented blocks of mixed mesophytic forest in the nation (Mahan 2004). GARI, DEWA and, potentially, UPDE also contain populations of the globally rare flatrock/riverscour plant communities. NERI and DEWA also contain an abundance and diversity of breeding neotropical migratory birds of potential global significance as is the abundance and diversity of salamanders at NERI (Mahan 2004). DEWA also contains a globally rare limestone fen community. The floral diversity at several network parks is of national significance and each of the parks also contain either globally rare or imperiled plant and animal species as well as state rare plant and animal species (Table 1.3 and "Appendix D – Species of Special Concern"). The unique geologic features of DEWA and NERI are of national significance, and many plant and animal populations and communities (such as the bat community at NERI) are of regional significance (Mahan 2004).

Table 1.3. Number of globally ranked (G1-G3) species within the Eastern Rivers and Mountains Network. "Appendix D – Species of Special Concern" contains a complete list of state listed species of special concern and their respective rankings.

Rank	#ERMN Species	Status	Description
Global 1	1	Critically Imperiled	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
Global 2	8	Imperiled	Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
Global 3	30	Vulnerable	Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.

1.3.4 Natural Resources Significant to Performance Management

Under the Government Performance and Results Act (GPRA) of 1993, NPS is required to set performance goals and report on the results of those goals to better achieve their mission and communicate more effectively with Congress and the public. Each park is required to develop similar performance goals that fall within the larger NPS framework. These goals are outlined in each park's Strategic Plan and Annual Performance Plan and progress is reported in the Annual Performance Report.

The servicewide GPRA goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). The servicewide long-term goal is to "acquire or develop 87% of the outstanding datasets identified in 1999 of basic natural resource inventories for all parks" based on the I&M Program's 12 basic datasets (http://science.nature.nps.gov/im/index.htm). Each year the ERMN continues to make progress towards meeting this goal.

For the purposes of the ERMN Monitoring Program, the parks' goals primarily fall within the NPS Goal Category I (Preserve Park Resources). This category includes the NPS goals of containing exotic species, improving the status of federally listed species and maintaining unimpaired water quality and restoration of disturbed lands, among others. The ERMN Monitoring Plan will identify monitoring indicators or "Vital Signs" of the network and develop a strategy for long-term monitoring to detect trends in resource condition (GPRA Goal Ib3). The network goal is to identify Vital Signs for natural resource monitoring by October 1, 2005. Other GPRA goals specific to ERMN parks that are, or may become, relevant to the ERMN Monitoring Plan are listed in Table 1.4.

Table 1.4. Government Performance and Results Act ("GPRA Goals") for each park that pertain to information generated by the Inventory and Monitoring program of the Eastern Rivers and Mountains Network.

GPRA Goal	Goal #	Parks with this goal
Preserve Park Resources	Ia	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Exotic plants contained Exotic animals contained	Ia1B Ia01B	ALPO, JOFL, FONE,FRHI, DEWA, UPDE, NERI, GARI, BLUE DEWA, NERI, GARI, BLUE
Improving federal T&E species or species of concern populations have improved status	Ia2A	DEWA, NERI, GARI, BLUE
Stable Federal Threatened & Endangered species or species of concern populations have improved status	Ia2B	NERI, GARI, BLUE
Species of concern populations have improved status	Ia2X	FONE, FRHI, DEWA
Water quality improvement	Ia4	ALPO, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Paleontological Resources	Ia9A Ia09A	DEWA NERI, GARI, BLUE
Natural resource inventories acquired or developed	Ib1; 1b01	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Vital signs for natural resource monitoring identified	Ib3	ALPO, JOFL, FONE, FRHI, DEWA, UPDE, NERI, GARI, BLUE
Geological Resources	Ib04	DEWA

See "Appendix C – Park Natural Resource Profiles" for a more in-depth discussion of the significant natural resources at each of the parks.

1.3.5 Integrated Water Quality Monitoring

The water resources of the ERMN are vast and span a gradient from large (relatively) free flowing rivers providing passage to anadromous and catadromous fish species to small vernal ponds that provide vital habitat for breeding amphibians. The ERMN has recognized from the beginning that the water resources of the network, whether in the form of precipitation or in water bodies, are a primary component of all the network ecosystems (see Chapter 2 for more detail). Therefore, we have sought to fully integrate the monitoring of water into the framework of the entire Vital Signs Monitoring Program.

In keeping with a holistic view of ecosystems, we view a continuum of land to water, rather than a line of demarcation. For any ecosystem, the abundance and distribution of water is probably one of the strongest driving forces of ecological change. However, for purposes of approaching water monitoring in a manageable context, we categorized our water resources into large rivers, riparian/floodplain communities, and tributary watersheds (which includes associated wetlands) (see Chapter 2). In this context, the network has decided to approach monitoring water quality by focusing not just on the chemical composition of the water, but also on the biological endpoints as well as anthropogenic stressors and atmospheric inputs to the system (see Chapter 2).

A report prepared to meet the policy and regulatory portion of the water resource information and assessment is presented in "Appendix G – Water Quality Summary" and summarized in Table 1.5. The information summarized in this report will serve to inform the development of an integrated water quality monitoring program. Water quality standards of the four network states were reviewed and summarized, as were other materials including the park "Baseline Water Quality Data Inventory and Analysis" reports (a.k.a Horizon Reports), current (year 2004) state lists of impaired water bodies (303(d) lists) under the Clean Water Act, and current data (September 2004) retrieved from the Environmental Protection Agency's (EPA) STORET (short for STOrage and RETrieval) water quality database. As part of these reports, information pertaining to site characteristics, past and current water quality problems, existing water quality monitoring stations and stream gages, and past and current water quality monitoring studies were summarized. This report was not intended to include and summarize park-based monitoring unless these data were uploaded to STORET.

The primary conclusions of this assessment are:

- Surface waters within the West Virginia (significantly) and Delaware River National Parks have been impaired by fecal coli form bacteria. Out-dated, short-circuiting and/or absent sewage treatment systems are the likely, and, in many cases, known cause of this impairment.
- Acid mine drainage has impaired waters within the West Virginia National Parks, JOFL, and FRHI.

- The Delaware River National Parks have a human health fish consumption advisory, and are listed on the PA 303d list for mercury and PCB contamination. These constituents been identified in fish tissue, and do not imply elevated concentrations in the water column.
- Very limited water quality information is available for ALPO, FONE, JOFL, and FRHI.

Table 1.5. Summary of Eastern Rivers and Mountains Network water quality information based on Clean Water Act assessment data and other pertinent state regulations (year 2004 data).

Park Code	Miles of Rivers and Streams	303(d) listed Streams (No.)	Impaired Length (stream-mi)	Criteria Affected	Cause	High Quality Streams (No.)	High Quality Miles (stream-mi)
DEWA	178.6	4	59.5	Arsenic, Benthic Macroinvertebrates, Cadmium, Chromium, Copper, Dissolved Oxygen, Dissolved Solids, Fecal Coliform, Lead, Mercury, Nickel, Nitrate, PCB, pH, Phosphorus, Selenium, Silver, Temperature, Total Suspended Solids, Unionized Ammonia, Zinc	Unknown, N/A	46 in PA 24 in NJ	66.7
UPDE	221.4	2	75.6	Mercury, PCB	Unknown	50 in PA N/A in NY*	37.7
JOFL	0.9	1	0.6	Metals, pH	Abandoned Mine Drainage	0	0
ALPO	5.3	0	0	None	None	0	0
FONE	3.7	0	0	None	None	8	3.7
FRHI	1.6	0	0	None	None	0	0
GARI	45.5	3	31.8	Aluminum (dissolved), Fecal Coliform, Iron, Manganese	Mine Drainage, Unknown	8	34.2
NERI	164.5	14	76.1	Aluminum (dissolved), CNA-Biological, Fecal Coliform, Iron, Manganese, pH	Mine Drainage, Unknown	13	83.7
BLUE	17.6	3	12.7	Fecal Coliform	Unknown	3	12.4

*New York does not have a "High Quality" designation.

1.3.6. Integrated Air Quality Monitoring

Under the Clean Air Act, park managers have a responsibility to protect air quality and related values from the adverse effects of air pollution. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution, as well as its impacts on resources. To be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. Through the efforts of park personnel, support office staff, and the NPS Air Resources Division, the NPS meets its clean air responsibilities by obtaining critical data and using the results in regulatory-related activities.

To further support the development of an integrated air resources monitoring program, the NPS Air Resources Division's Air Information System (ARIS) provides information on:

- Location of air quality (deposition, particulate matter, ozone, visibility) monitoring stations in and around the ERMN
- Ozone risk assessment for ERMN parks
- Summary of ERMN Air Quality Related Values (ARQVs)
- Summary of air quality monitoring considerations for the ERMN

Each can be located at: http://www2.nature.nps.gov/air/permits/aris/networks/ermn.cfm and will be used to help develop an integrated air quality monitoring program.

1.3.7 Overview of Current Monitoring and Partnership Opportunities

The Natural Resource Challenge (NRC) represents the first service-wide effort to fund long-term monitoring. While the Inventory and Monitoring portion of the NRC is an opportunity to establish new facets of an ecological monitoring program, it is important to also examine past and current monitoring conducted by parks and their neighbors. Doing so will allow us to build upon those efforts and gain the maximum amount of understanding of park natural resources.

The focus of this section is on monitoring that is occurring by both the parks and their partners and neighbors. Each of the parks were asked about monitoring programs that are currently occurring within park boundaries. The results of this inquiry and input from ERMN staff are summarized in Table 1.5 and "Appendix E – Park Monitoring Programs". All existing air quality monitoring stations are depicted in relation to ERMN parks and summarized at http://www2.nature.nps.gov/air/permits/aris/networks/ermn.cfm. Similarly, figures and descriptions of existing (does not include all NPS sites) water quality monitoring stations and flow gages are presented in "Appendix G – Water Quality Summaries".

A list of national, state and university organizations with monitoring (or other relevant) programs outside or adjacent to park boundaries, or which can be viewed as potential collaborators on future monitoring programs, can be found in "Appendix F – Outside Park Monitoring and Potential Collaborators".

Table 1.6. Summary of Eastern Rivers and Mountains Network park-based monitoring prior to the Vital Signs Monitoring Program (2004). See "Appendix E –Park Monitoring Programs" for more specific information and descriptions of these monitoring programs.

Level 1 Category	Level 2 Category	Level 3 Category	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Air and Climate	Air Quality	Ozone							X		
		Wet and Dry Deposition	X				X				
	Weather and Climate	Weather and Climate	X						X		
Water	Hydrology	Surface Water Dynamics					X	X			

Level 1 Category	Level 2 Category	Level 3 Category	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
	Water Quality	Water Chemistry - Core	X				X	X	X	X	X
		Water Chemistry - Expanded	X				X	X	X	X	X
		Aquatic Macroinvertebrates	X				X	X	X		
		Aquatic Periphyton							X		
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	X	X			X	X	X		
	Focal Species or Communities	Shrubland Forest and Woodland Communities					X		X	X	
		Riparian Communities							X		
		Birds - Riparian Communities							X		
		Birds – Breeding Communities					X		X	X	X
		Fish Communities - Rivers							X		
		Amphibians and Reptiles					X				
	At-risk Biota	T&E Species & Communities - State						X	X	X	
		T&E Species & Communities - Federal					X	X		X	X

1.3.8 Dominant Management Issues of Eastern Rivers and Mountains Network Parks

Five ERMN parks are dominated by large rivers (NERI, GARI, BLUE, DEWA and UPDE) and main-stem water issues are of principal concern for aquatic natural resources and human health associated with water-based recreation. Issues include adequate water flow and the frequency, timing, and duration of high and low flow events (from natural flow to dam releases to catastrophic flooding); significant problems with treated and untreated sewage; acid mine drainage from abandoned mines and associated mining spoils; altered water chemistry from a variety of point and non-point sources; invasive exotic species; and the potential for a catastrophic chemical spill from neighboring highway and railway systems. These issues are complicated by the fact that the drainage area for these rivers is very large with the majority of the contributing land area falling outside park property. These "bottom-of-the-watershed" parks engage, and must continue to engage, in multi-agency, multi-stake holder, regional efforts for effective management of their water resources.

Water quality issues in ERMN parks are not limited to main-stem rivers. Many parks are faced with water issues associated with smaller rivers and headwater streams as well. Many of the issues are the same as for the main-stem rivers, yet are on a smaller scale and, therefore, somewhat more directly tangible to park-based management. Still, because many of these parks were generally designated around a river (and are narrow and linear in shape), the headwaters of almost all tributaries and streams fall outside of park property. What's more, headwater areas often make up more than two-thirds of the land area of a drainage network. As such, headwater stream water quality is directly tied to land-use surrounding the park units. The dominant issue facing all parks, albeit at different levels of urgency, is development pressure and the adverse ecological effects that come with it. Because many of the ERMN parks are within a few hours' drive of growing metropolitan areas such as New York, Washington, Baltimore, Pittsburgh, and

Philadelphia, landscapes surrounding parks are being increasingly altered by first and second home development. Most pressing is the construction of homes (and associated infrastructure) around DEWA and UPDE due to the proximity of metropolitan New York and New Jersey. This issue is also of concern at the other four Pennsylvania parks and will be an increasingly important issue at NERI, GARI, and BLUE as development pressure being driven by outdoor recreational enthusiasts and vacation home developers, mounts. In the meantime, tributary stream water quality at NERI, GARI and BLUE is significantly affected by a lack of adequate sewage and septic facilities in West Virginia creating a human as well as natural resource threat. Again, local and regional involvement and cooperation is required to address these issues.

Terrestrial issues are somewhat more tractable to park-based management since a focus can be placed on lands within the park boundary. Yet again, many issues emanate from outside the park including outbreaks of exotic pests such as dogwood anthracnose (caused by the fungus *Discula* sp.), beech bark disease (the disease results when bark, attacked and altered by the beech scale, *Cryptococcus fagisuga* Lind., is invaded and killed by fungi, primarily *Nectria coccinea* var. *faginata)*, gypsy moth (*Lymantria dispar*), hemlock wooly adelgid (*Adelges tsugae)* and a suite of invasive plant species. Overbrowsing by white-tailed deer (*Odocoileus virginianus)* is also a problem at many of the parks and has the potential to negatively affect forest regeneration and the viability and persistence of many rare plant species. Although many of the larger ERMN parks do allow hunting within their borders, it is impossible to regulate movement of deer in and out of the parks. Regional air quality issues such as ozone and acidic deposition also affect resources at these parks. Also of regional significance is the maintenance of large unbroken blocks of forested habitat. Many of these parks have significant forested areas that may only maintain their significance as part of a much larger forested landscape (i.e., as part of forested lands outside the park boundary). Issues such as timber harvesting and development pressure outside the park are relevant in this context as well.

Many of these parks are mandated to maintain a variety of open spaces for cultural interpretation and other reasons. These areas range from active agricultural fields and fallow fields to herbaceous meadows and shrublands. Management of these areas has great potential to meld cultural objectives with meaningful natural resource objectives. For example, shrubland birds and butterflies are abundant in many of these areas and may sustain viable populations with only slight modifications to cultural management prescriptions.

Finally, for parks such as DEWA and NERI which have over 1 million visitors each year, impacts from recreational uses is also a concern. Both NERI and GARI are popular rafting and climbing destinations, and overuse or misuse by visitors can impact rare or threatened communities and species within the park. All network parks also have the potential for negative visitor impacts since all are used extensively for day uses including hiking, camping, hunting (in some cases), fishing and road travel.

See "Appendix C – Park Natural Resource Profiles" for additional and more in-depth discussions of natural resources and prevalent management issues at each of the parks.

1.4 Development of Management, Monitoring, and Sampling Objectives

The ERMN monitoring program objectives are more specific statements that provide additional focus about the purpose or desired outcome of the program beyond the five servicewide program goals (Section 1.2.2). The ERMN will develop, in conjunction with network parks, the three types of objectives that are commonly presented in the ecological monitoring literature (e.g., Elzinga et al 1998): management objectives, sampling objectives, and monitoring objectives. These more specific management, monitoring, and sampling objectives will be developed during Phase III.

Management objectives provide focus about the desired state or condition of the resource, and provide a measure of management success. As described by Elzinga et al. (1998:46), management objectives can usually be classified as one of two types: (1) target/threshold objectives (e.g., increase the population size of Species A to 5000 individuals; maintain a population of a rare plant Species B at 2500 individuals or greater; keep Site C free of invasive weeds X and Y); or (2) change/trend objectives (e.g., increase mean density of Species A by 20%; decrease frequency of invasive weed X by 30% at Site C).

Sampling objectives are usually written as companion objectives to management or monitoring objectives. Sampling (or statistical) objectives specify information such as target levels of precision, power, acceptable Type I and II error rates, and magnitude of change you are hoping to detect. An example of a sampling objective is as follows:

- We want to be 90% certain of detecting a 40% change in bird density and we are willing to accept a 10% chance of saying a change took place when it really didn't.

Monitoring objectives provide additional detail about what the monitoring program or sampling protocol will do. Table 1.2 summarizes the initial, general ecosystem monitoring objectives for the ERMN. These general objectives provide some additional focus to the program and were used to help prioritize vital signs (see Chapter 3). For purposes of a sampling protocol (to be developed during Phase III and beyond), however, the set of monitoring objectives will be refined to reflect more specific details and coupled with management and sampling objectives.

Table 1.7. General Monitoring Objectives for Eastern Rivers and Mountains Network Vital Signs.

Level 1 Category	Level 2 Category	Level 3 Category	General Monitoring Objectives
Air and Climate	Air Quality	Ozone	Document status and monitor trends in ozone concentration surrounding the ERMN and/or ozone injury occurring in sensitive plant species in the ERMN.
		Wet and Dry Deposition	Document status and monitor trends in atmospheric pollutant concentrations present in the ERMN and/or deposition injury to sensitive species in the ERMN.
	Weather and Climate	Weather and Climate	Monitor key measurable climate parameters to determine rate and extent of climate trends in the ERMN.
Geology	Geomorphology	Stream/River Channel	Monitor changes in geomorphology of stream/river bank and other

Level 1 Category	Level 2 Category	Level 3 Category	General Monitoring Objectives
and Soils		Characteristics	riparian features in the ERMN.
	Soil Quality	Soil Erosion and Compaction	Document condition and monitor trends in soil compaction and/or erosion in the ERMN.
		Soil Function and Dynamics	Document condition and monitor trends in soil function and dynamics in the ERMN.
Water	Hydrology	Surface Water Dynamics	Document the status and trend of surface water quantity in the ERMN, including flow in streams and rivers.
		Wetland Water Dynamics	Document the status and trend of water quantity in vernal ponds and other wetlands.
		Groundwater Dynamics	Document the status and trend of groundwater quantity.
	Water Quality	Water Chemistry - Core	Document status and trend in core water chemistry parameters in the ERMN.
		Water Chemistry - Expanded	Document status and trend in an expanded suite of water chemistry parameters.
		Aquatic Macroinvertebrates	Document status and monitor trends in select indicator groups of aquatic macroinvertebrates.
		Aquatic Periphyton	Document status and monitor trends in composition, abundance and/or extent of select algae and other periphyton.
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	Document status and trends in established populations of invasive species and diseases, including response to treatment.
		Invasive/Exotic Plants, Animals and Diseases – Early Detection	Use monitoring data for early detection & predictive modeling of incipient invasive species and diseases.
	Focal Species or Communities	Shrubland Forest and Woodland Communities	Document status and trends in plant community composition, structure & dynamics in the ERMN.
		Riparian Communities	Document trends in riparian vegetation community composition, structure, and dynamics in the ERMN.
		Birds - Riparian Communities	Document status and monitor trends in community composition, species abundance, and/or demographic rates of select riparian birds.
		Mammals – Riparian Communities	Document status and monitor trends in presence, distribution and/or abundance of select riparian mammals.
		Birds – Breeding Communities	Document status and monitor trends in community composition, species abundance, and/or demographic rates of bird communities.
		Terrestrial Invertebrates	Document status and monitor trends in community composition, diversity, richness, abundance etc. of select terrestrial invertebrates
		Freshwater Communities - Crayfish	Document status and monitor trends in community composition and/or species abundance of freshwater crayfish.
		Freshwater Communities - Macrophytes	Document status and monitor trends in composition, abundance and/or extent of select aquatic macrophytes.
		Fish Communities - Streams	Document status and monitor trends in community composition, species abundance, and/or demographic rates of stream fishes.
		Fish Communities - Rivers	Document status and monitor trends in community composition, species abundance, and/or demographic rates of select riverine fishes.
		Amphibians and Reptiles – Vernal Pond Community	Document status and monitor trends in community composition, species abundance, and/or demographic rates of vernal pond inhabiting amphibians.

Level 1 Category	Level 2 Category	Level 3 Category	General Monitoring Objectives
		Amphibians and Reptiles – Streamside Salamander Community	Document status and monitor trends in community composition, species abundance, and/or demographic rates of streamside salamanders.
		Amphibians and Reptiles	Document status and monitor trends in community composition, species abundance, and/or demographic rates of select reptiles and amphibians.
	At-risk Biota	T&E Species & Communities - State	Document status and monitor trends in select populations of State threatened, endangered, or at-risk species within the ERMN.
		T&E Species & Communities - Federal	Document status and monitor trends in select populations of Federally threatened or endangered species within the ERMN.
Human use	Point-Source Human Effects	Bioaccumulation	Conduct monitoring of toxicity levels in select species of fish, mammals and other species at risk.
	Visitor and Recreation Use	Visitor Use	Document changes in visitation and in spatio-temporal patterns of park use by visitors that impact select natural resources.
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	Document changes in development and land conversion in and around ERMN park watershed boundaries.
		Landscape Pattern	Document status and monitor trends in a suite of landscape metrics including area of dominant land cover types, patch shape, size, and connectivity, etc.
	Energy Flow	Primary Production	Document status and trends in ecosystem primary production rates.
	Nutrient Dynamics	Nutrient Dynamics	Document status and trends in key ecosystem nutrient cycles.

CHAPTER 2 -- CONCEPTUAL ECOLOGICAL MODELS

In Chapter 2 of the Eastern Rivers and Mountains Network Monitoring Plan we present an overview of the conceptual ecological models developed (presented in their entirety as Appendices H-J) to guide design of the program thus far. These models, and revisions and updates of each, will also serve as the ecological foundation for interpreting monitoring data.

Conceptual models are important throughout all phases of development of a monitoring program. Early in the process, simple conceptual models provide a framework that relates information in discussions and literature reviews to a broader context - it is a structure to organize information. Learning that accompanies the design, construction, and revision of the models contributes to a shared understanding of system dynamics and appreciation of the diversity of information needed to identify an appropriate suite of ecosystem indicators.

Conceptual models provide a mental picture of how something works, with the purpose of communicating that explanation to others. Models (of all types) work best when they include only the minimum amount of information needed to meet the model's purpose (Starfield 1997). Conceptual models play several useful roles in monitoring program design, including:

- formalizing current understanding of the context and scope of the ecological processes important in the area of interest;
- expanding our consideration across traditional discipline boundaries, fostering integration of biotic and abiotic information; and
- facilitating communication among scientists from different disciplines, between scientists and managers, and between managers and the public (Thomas 2001).

The key point about conceptual models is their role in communication among people with different points of view (Abel et al. 1998). Conceptual models can take a variety of forms—from narrative descriptions to schematic diagrams or flowcharts with boxes and arrows. Regardless of form, the success of a model depends on its ability to share viewpoints and develop a common understanding based on multiple viewpoints.

Unfortunately, no single model form describes an entire system adequately. Model generality is needed to characterize broad-scale influences and relationships among park resources, while model specificity is required to identify detailed relationships and components in the system that can be effectively monitored (i.e., measured/sampled) and subsequently managed. Consequently, both broad-scale models and specific models are needed to adequately represent ecological systems contained within large areas the size of national parks. Because of this need, the ERMN began with broad-scale models to help support the selection of vital signs and will continue to develop more specific models (and review appropriate literature) needed for determining appropriate measures, detection limits, acceptable ranges of variation in those measures, and management trigger-points.

As such, the conceptual models presented herein and in Appendices H-J do not represent finished products; the process of thinking about, developing, discussing and revising conceptual models provides the greatest benefit to the users and should be considered an iterative process.

Conceptual models are based on concepts that can and will change as monitoring provides new knowledge about ecosystem interactions.

The purpose of this chapter and the associated Appendices is to explain our current understanding of ecological interactions, and how stressors and other agents of change affect selected natural resource components and processes in ERMN parks. The models are intended to serve as narrative and pictorial illustrations of the conceptual foundation for monitoring presented in Chapter 1 and support the identification and selection of ecological vital signs for long-term monitoring (Chapter 3).

2.1 ERMN Approach to Conceptual Model Development

As first discussed in Section 1.2.3, the ERMN grappled with the question; "Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status?". The answer to this question seemed to dictate whether the network would develop stressor-based conceptual models (identifying ecosystem stressors and linkages to ecosystem components) or system-control type models (identifying ecosystem dynamics, feedbacks, controls, etc.). What was perceived as a mutually exclusive choice led to many fits and starts, dead ends, and frustrations with model development. It seemed logical to develop stressor-based models (as presented in the Phase I Report) since this approach would result in the selection of vital signs that provide data most directly relevant to management actions. Park managers generally wanted data to address whether the most critical threats (and their effects on park resources) that confront natural resources at a park were changing in their severity or geographic scope as a result of management actions (or lack thereof). Clearly, without reduction in the threats to park natural resources, those species and ecosystems that are the focus of park management will rapidly degrade and disappear. While this stressor-based approach had, and continues to have, value, the models as initially developed (see Phase I Report) lacked the explicit link and description of how these stressors are believed to impact and alter ecological systems. These so called "ecological effects" were implied, rather than explicitly discussed.

Further, however important, measuring threat status is insufficient on its own for several reasons. First, a focus on threat status alone must assume that there is a clear, often linear, relationship between a threat and the status of the resource. This runs counter to recent evidence of the nonlinear dynamics of ecosystems, time lags in response, and threshold effects (e.g., Scheffer et al. 2001; Limburg et al. 2002). Second, a singular focus on current threats, while critical to prompt and appropriate management action, leaves a monitoring program vulnerable to the inability to detect future, currently unforeseen threats and issues.

It seemed then, the best way to meet the challenges of monitoring in national parks is to achieve a balance among different monitoring approaches (termed the "hybrid approach" by Noon 2003) and to include both threat-specific monitoring (monitor the threats themselves along with the ecological response) and also monitor subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall status or condition of park resources (as describes in Section 1.2.3). As such, the network had to take a step back and refocus the conceptual models to not only include threats but also to place the models within a general theoretical framework for thinking about ecosystem level processes and dynamics.

The steps outlined below, then, to develop our initial conceptual ecological models, while presented in sequential order for clarity, actually reflect a very dynamic and iterative process that, by definition, will continue to be modified and revisited over time.

2.2 Overview of Conceptual Models

2.2.1 Identify Ecological Systems for Model Development

The first step in the development of conceptual models was to identify ecological systems for model development. Ecosystems were chosen for their overall significance to the parks and to regional biodiversity (see Chapter 1), as well as for the potentially different attributes or processes that characterize them. With obvious overlap between them, the ERMN identified three dominant ecosystems: large rivers, tributary watersheds (and associated wetlands), and terrestrial ecosystems for initial, broad-scale conceptual modeling. It also later became apparent that a fourth broad and critically important system in the network, riparian and floodplain communities, warranted independent model development (Figure 2.1).

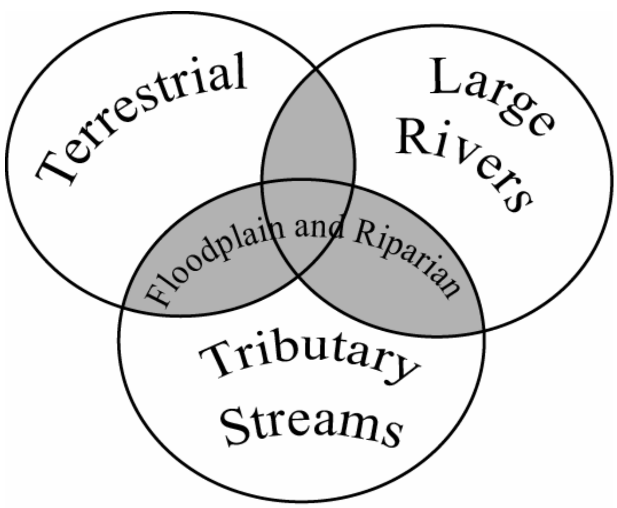


Figure 2.1. Broad-scale, dominant ecosystems within the Eastern Rivers and Mountains Network chosen for conceptual ecological model development.

2.2.2 Identify Theoretical Framework

The next step in model development was to identify a general theoretical framework for ecosystem level models. In conjunction with the cooperators developing each of the system models, the network elected to build upon the theoretic frameworks developed by Jenny (1941, 1980) and Chapin et al. (1996) for the terrestrial and riparian ecosystems and that developed by Karr (1991, 1999) and others for river and tributary stream ecosystems. While these approaches have differences, the similarities are more evident because they both focus on key ecosystem "factors" essential to the conservation, maintenance, and sustainability of ecosystem properties.

Jenny (1941, 1980) and Chapin et al. (1996) proposed that a sustainable ecosystem is one that, over the normal cycle of disturbance events (i.e., decades to centuries), maintains its characteristic diversity of major functional groups, productivity, soil fertility, and rates of biogeochemical cycling (Chapin et al. 1996). Ecosystem properties are governed by internal interactions and external factors. Five independent external *state factors* (parent material, climate, topography, potential biota, and time since disturbance) determine limits of ecosystem processes. These state factors are, in turn, modified by a set of four dynamic, *interactive controls*: local/regional climate, soil/water resource supply, major functional groups of organisms, and disturbance regime. In contrast to state factors, interactive controls both control <u>and</u> respond to ecosystem characteristics; they are both constrained by state factors and respond to ecosystem processes (Chapin et al. 1996). For vital signs monitoring, a key component of the Jenny-Chapin framework is the hypothesis that interactive controls must be conserved if an ecosystem is to be maintained, and that major changes in any interactive control will result in a new ecosystem with distinctly different properties.

The river and stream models began with and modified Karr's (1991, 1999) basic conceptual model of stream ecosystems. The model focuses on biological and ecological endpoints in the context of ecological integrity ("integrity" applies to the condition of systems at one end of a continuum of human influence: those that support a biota that is the product of evolutionary and biogeographic processes with minimal influence from modern human society *sensu* Karr 1999) and five factors (flow regime, water quality, energy source, biological interactions, and physical habitat) that influence or modify the components of ecological integrity. Similar to the interactive controls of the Jenny-Chapin framework, these five factors provide a critical conceptual and analytical framework to judge (i.e., monitor) the interactions of human activities and ecological change.

Key ecosystem processes include geophysical/hydrological, biological, and ecological components. Geophysical processes include land cover, land use, and landscape patterns. Across a landscape, habitat diversity, connectivity, isolation, and landscape change are important components of the geophysical setting. Soil composition and chemistry, and the rate of weathering of parent material, and water quality all determine site productivity and quality. Biological processes are defined by compositional and structural characteristics of the biota on the individual, community, and landscape level. Taxonomic composition, fecundity, growth, health, vigor, and survival and mortality are components. Key indicators of a healthy and sustainable biota are biodiversity and compositional resilience, including both rare species and invasive species populations. Ecological processes include those that cycle energy and materials through the system—the biogeochemical links between organisms and their environment. Primary productivity, nutrient cycling, water cycling, decomposition and mineralization, and food webs are key ecological processes.

We were now able to think about and visualize our dominant ecosystems in a framework explicitly designed to focus the reader on to those key ecosystem "factors" or "controls" critical to the inherent character and sustainability of the system (Figure 2.2; emphasis on the Jenny-Chapin model).

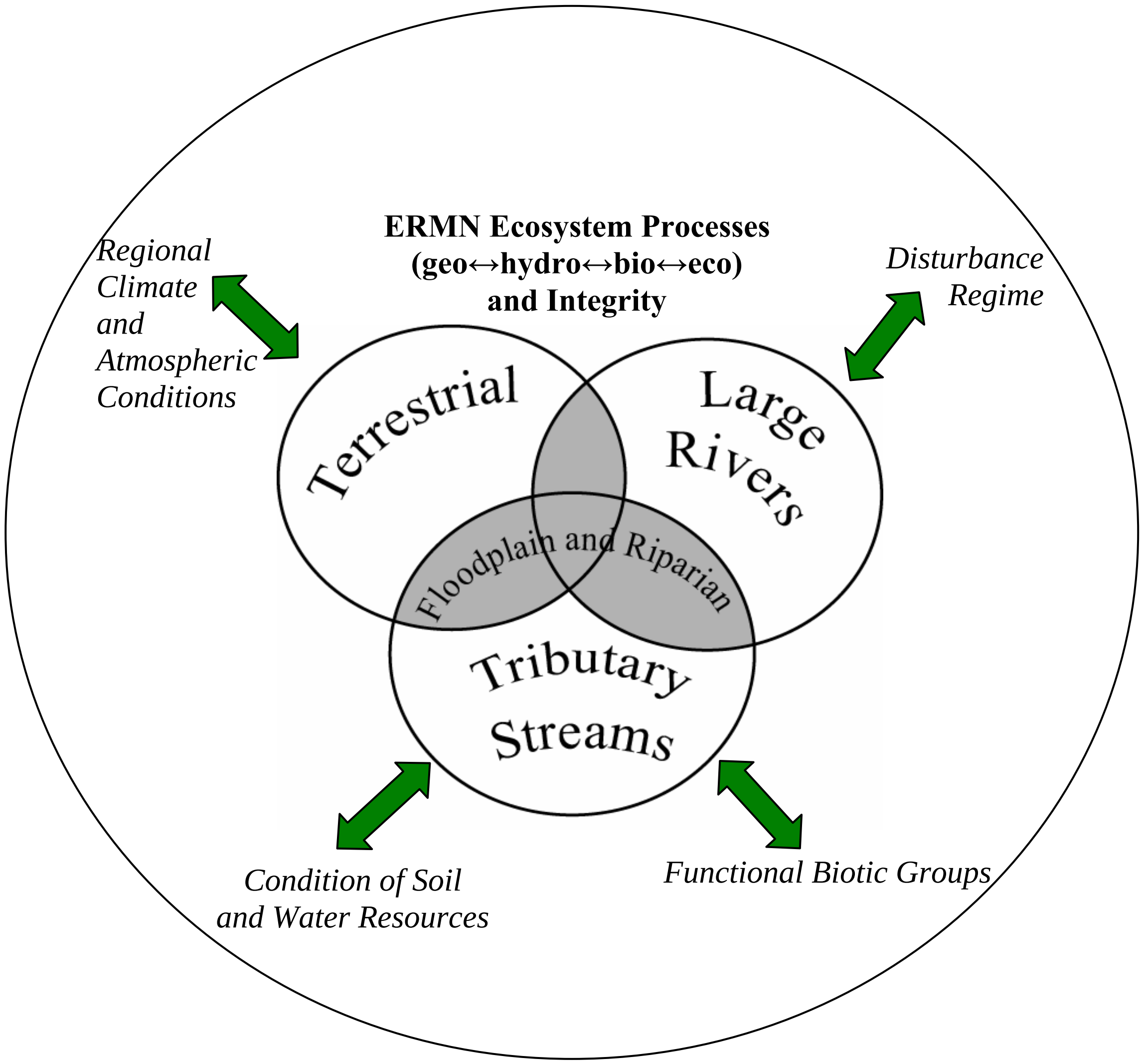


Figure 2.2. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (italicized) and broad-scale ERMN ecosystems, processes and integrity. Interactive controls must be conserved if ERMN ecosystems are to be maintained.

2.2.3 Adding Anthropogenic Stressors and Known or Hypothesized Ecological Effects

Once the a more general theoretical framework was in place, we could then go back and add the stressors we had previously identified during development of the Phase I Report in the appropriate context of how we expect/hypothesize the system to be effected (Figure 2.3). A literature review and descriptions of the major agents of change, stressors and the known or hypothesized ecosystem response, or measurable change in the system structure, function, or process was accomplished primary in narrative and graphical format in the respective Appendices (H, I, and J).

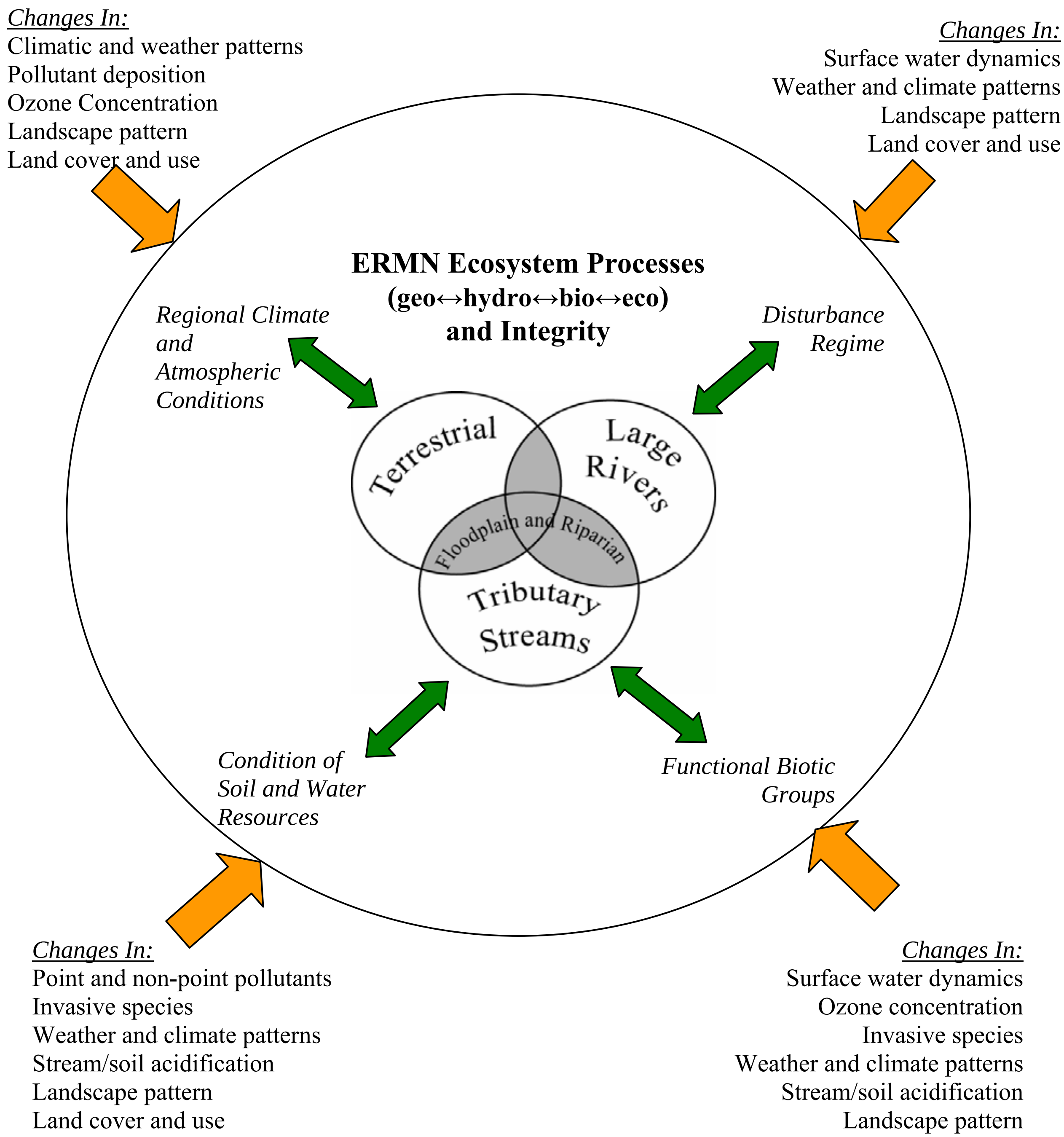


Figure 2.3. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (italicized) and broad-scale ERMN ecosystems and processes and integrity. Interactive controls must be conserved if ERMN ecosystems are to be maintained. Major changes (natural or anthropogenic) in any interactive control will result in a new ecosystem with distinctly different properties.

2.2.4 Summary and Link to Vital Signs

As a result of the conceptual modeling exercise for each respective system, the cooperators conducting the literature review and developing the models were then able to draw upon their work (summarizing key system properties, stressors, and the relationship among stressors, ecological effects and responses) to propose a candidate list of vital signs for consideration by the network and others (see Chapter 3). A shorter, summary narrative for each of these candidate vital signs is included in each respective conceptual model (see Appendices H-J).

Narrative and graphical models for each of these systems are presented in their entirety in the following appendices:

Appendix H: Structure and Function of Terrestrial Ecosystems in the ERMN: Conceptual Models and Vital Signs Monitoring.

Appendix I: Structure and Function of Tributary Watershed Ecosystems in the ERMN: Conceptual Models and Vital Signs Monitoring.

Appendix J: Structure and Function of Large River Ecosystems in the ERMN: Conceptual Models and Vital Signs Monitoring.

(Riparian/Floodplain community models are under development and are not yet available.)

CHAPTER 3. VITAL SIGNS

The term vital sign is defined in this program as "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (http://science.nature.nps.gov/im/monitor/). In this chapter, we describe the vital signs for the Eastern Rivers and Mountains Network and the process used to select and prioritize these vital signs.

In summary, the Eastern Rivers and Mountains Network has identified 37 vital signs that represent a systems approach to our monitoring program. Three vital signs relate to air and climate, three relate to geology and soils, five relate to water, two relate to human use, four relate to ecosystem pattern and processes, and 20 relate to biological integrity. The network developed this list through a process of meetings and ranking exercises to produce a priority list of vital signs we plan to implement or develop in the next three to five years.

3.1 Process for Choosing Vital Signs

The process for choosing and prioritizing vital signs has been ongoing within the Eastern Rivers and Mountains Network since the fall of 2003 and has been a multifaceted process of park-level scoping workshops, subject matter expert evaluation, a broad vital signs prioritization workshop, park-level rankings, Science Advisory Committee review (scheduled for fall 2005), and Board of Directors approval (scheduled for fall 2005). Over the last year we have focused the vital signs list and placed it within the conceptual models for the network. The following sections (fully developed in Appendix K – Vital Signs Prioritization Process) summarize the major steps in the ERMN process for choosing vital signs.

3.1.1 Park Scoping Sessions

To initiate discussion of vital signs, we held park-level brainstorm sessions beginning in fall 2003 and culminating in winter 2005 with each network park's staff. The purpose of these sessions was to present the Vital Signs program and draft lists of candidate vital signs to all interested park staff and to informally receive their input on these potential vital signs for the park and network. Based on these sessions, and especially the winter 2005 meetings, a long list (n = 61) of potential vital signs was developed (see Appendix K – Vital Signs Prioritization Process for full list).

The generation of this list was achieved primarily through these series of park scoping meetings to discuss park resources, management issues and species or communities of special concern, but also through the review of park Resource Management Plans, Water Management Plans, and other reports and relevant documents; results of the Geologic Resource Evaluations (Summer 2004); discussions with and reports by ERMN inventory cooperators; and any planned or opportunistic discussions with park natural resource staff as well as Regional I&M staff. The initial draft of this master list, in essence, was the best attempt by network staff to assimilate and interpret all the information gained on park resources and potential monitoring needs during the formulation of the Phase 1 Report and beyond. This master list of potential vital signs was the first major milestone in the vital signs selection and prioritization process.

3.1.2 Science Advisory Committee Formulates Remaining Plan

The process by which the network would begin to shorten (or otherwise modify) the master list of vital signs was decided upon at a December 2004 meeting of the ERMN Science Advisory Committee (SAC) at University Park, Pennsylvania. Though some details were left to be determined at a later date, the following represents the general process and workflow that the SAC suggested for the ERMN (see Appendix K for a detailed description of the ERMN Prioritization Process):

- Pare down master list to a more manageable short list of vital signs by subject matter experts based on ecological significance and potential as indicators;
- Hold vital signs prioritization workshop that will serve as peer review of prior step by larger science and NPS communities;
- Prioritize short list by park staff based on management significance and legal mandate;
- Integrate park and workshop feedback at network and the SAC level; and
- Allow ERMN Board of Directors to review and approve final, short list of vital signs.

The network received approval by the ERMN Board of Directors in January 2005 to undertake this process for prioritizing network vital signs. Moreover, implicit in this process was the understanding that the entire process and outcome would be reviewed and evaluated at Regional and National I&M levels.

3.1.3 Subject Matter Experts

The next stage in refining the list of vital signs involved forming a core team of subject matter experts to shorten the list of vital signs based on a literature review and best professional judgment. ERMN resources were separated into three dominant ecosystem types: large rivers, terrestrial, and tributary stream watersheds and subject matter experts were solicited for each. Two of the three teams were simultaneously drafting or revising the network conceptual models as well and therefore could use all of the insights gained from that process to inform their recommended short-list of vital signs. Of significance was that each team was not limited to the master list of 61 candidate vital signs and could, if desired, add additional vital signs to the list. Each team was to focus on ecological significance (as opposed to park management significance) and was provided with the following criteria on which to base their recommendations:

Ecological Significance:

- There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent.
- The vital sign represents a resource or function of high ecological importance based on the conceptual model of the system and the supporting ecological literature.
- The vital sign provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system.

- The vital sign is sufficiently sensitive to detect specified change; has a high signal to noise ratio and does not exhibit large, naturally occurring variability.

This step in the process reduced the master list of 61 vital signs to a short list of 36 that were recommended by the core planning team. This core planning team of experts also produced summary narratives for each recommended vital sign that included the following topics:

- Brief Description of Vital Sign
- Significance/Justification
- Proposed Metrics
- Prospective Method(s) and Frequency of Measurement
- Limitations of Data and Monitoring
- Key References
- Related Environmental Issues and Linked Vital Signs
- Overall Assessment

These original summary narratives are presented in their entirety with the corresponding and respective conceptual models in Appendices H, I, and J. Appendix A contains the most current list of network vital signs and the most current vital sign summary narratives.

This short list of 36 priority vital signs was the second major milestone in the vital signs selection and prioritization process.

3.1.4 Vital Signs Prioritization Workshop

On May 19-20, 2005 network staff held a vital signs prioritization workshop at Pennsylvania State University that included 51 professionals with diverse backgrounds and expertise including all member of the ERMN SAC and at least one representative from each ERMN park (see Appendix K for detailed summary of the agenda, participants, materials, and results of this workshop). The workshop was organized around the dominant ecosystem types with working groups for each led by the core team of subject matter experts who did the initial paring down of vital signs (Section 3.1.3 above). This workshop provided an opportunity for the core planning team of subject matter experts to present their work (justification for paring down the master list of vital signs and development of linkages to the conceptual models) for review by peers in the scientific community, and an opportunity for the scientific community to participate in the vital signs prioritization process of the network. During this workshop the current short list of priority vital signs (from Section 3.1.3 above) could have been modified (additions/subtractions/etc.) depending on group process, discussion and consensus.

The workshop was designed to meet two objectives. The first objective was to reach scientific consensus on a proposed short list of priority vital signs for the ERMN. The second objective was to further evaluate the merits of individual vital signs and priority group them into “tiers” for implementation (with “tier-1” being the highest priority vital signs for protocol development and implementation and “tier-3” the lowest).

The final result of the ERMN vital signs prioritization workshop was a short-list of tier-ranked vital signs based on ecological significance that had been peer-reviewed, is justifiable, supported by conceptual ecosystem models, and upon which there is general scientific consensus.

The workshop participants started with the 36 candidate vital signs, dropped 3 from further consideration (White-tailed Deer, Mosses Lichens and Bryophytes, and Phenology), added two new vital signs (Indicator Taxa and Terrestrial Mammals), and also lumped and split several vital signs. In the end, the workshop ended with the same number (36) of vital signs although some were different than when they began (Table 3.1). Please refer to Appendix K for a more detailed summary of workshop events and outcomes.

This short list of 36 potential vital signs was the third major milestone in the vital signs selection and prioritization process.

3.1.5 Park Management Significance Rankings

Following the prioritization workshop based on ecological significance, we distributed the short list of network vital signs to solicit input from park staff once again. Parks were presented with the short list of vital signs from all three ecosystem types resulting from the workshop and asked to prioritize these vital signs according to management significance and legal mandate. Park staffs were not presented with results of the tier rankings based on ecological significance done at the workshop. Evaluation of each vital sign in terms of management significance was done according to the following criteria and scoring (based on other national programs, including other NPS Vital Sign Monitoring Networks):

Park Management Significance:
- Legal/policy mandate: How important is monitoring this resource/vital sign for satisfying legal or policy mandates? [3=high importance (required), 2=moderate importance (specifically identified), 1=low importance (generally identified)]
- Potential to support management decisions: Does monitoring this vital sign directly link to the information needed for carrying out a key management decision or evaluating the outcome of a management decision? [3=strong application, 2=moderate application, 1=weak application]
- Importance of resource management: How important (for management) is the resource or issue represented by the vital sign, relative to other resources or issues in the park? [3=high importance, 2=moderate importance, 1=low importance]
- The indicator will produce results that are clearly understood and accepted by park managers, other policy makers, and the general public, all of whom should be able to recognize the implications of the indicator's results for protecting and managing the park's natural resources. [3=clearly understood, 2=generally understood, 3=poorly understood]

While much of this thought process went into the generation of the original candidate list of 61 vital signs (see Section 3.1.1), the park staffs never had an opportunity to explicitly rank each vital sign based on management priorities. The criteria and scoring of each would result in a total score ranging from a low of 4 to a high of 12. Park staffs were encouraged to rank only the list of

36 provided to them, but certainly could propose that a new vital sign be added to the list (only one was added: Freshwater Communities: Mussels).

Once this park ranking process was underway, it became clear that it would also be useful for the parks to report management significance scores in the simple "tier 1-3" framework as was done at the workshop. Thus, each park ultimately provided scores under both ranking systems (Table 3.1).

The ranking of the short list of 36 potential vital signs based on park management significance by ERMN park staff was the fourth major milestone in the vital signs selection and prioritization process.

Table 3.1. Vital Signs for the Eastern Rivers and Mountains Network presented in the national 3-category framework with associated ecological and management significance rankings. "Final" refers to the final network rank based on an assimilation of the workshop ecological significance ranking process ("Workshop") and the respective park management significance ranking process ("Park Codes"). Tier-rankings (1 = highest, 3 = lowest) refer to the suggested priority in which vital signs should have protocols developed and implemented.

			Tier Ranks (Final Network Rank, Workshop Rank, and Park Management Ranks)										
Level 1 Category	**Level 2 Category**	**Level 3 Category "Vital Sign"**	**Final Rank**	**Work Shop**	**ALPO**	**JOFL**	**FONE**	**FRHI**	**DEWA**	**UPDE**	**NERI**	**GARI**	**BLUE**
Air and Climate	Air Quality	Ozone	2	2	2	2	2	3	3	3	3	3	3
		Wet and Dry Deposition	1	1	1	1	3	3	2	2	2	2	2
	Weather and Climate	Weather and Climate	1	2	1	2	3	3	2	3	1	1	1
Geology and Soils	Geomorphology	Stream/River Channel Characteristics	2	1.5	3	3	2	2	2	2	1	1	1
	Soil Quality	Soil Erosion and Compaction	3	3	3	3	3	3	3	3	2	2	2
		Soil Function and Dynamics	2	2	3	3	3	3	3	3	2	2	2
Water	Hydrology	Surface Water Dynamics	1	1	2	2	3	3	1	1	1	1	1
		Wetland Water Dynamics	2	1	2	1	1	2	3	3	2	2	2
		Groundwater Dynamics	2	3	3	3	1	2	3	2	2	2	2
	Water Quality	Water Chemistry - Core	1	1	1	1	1	1	1	1	1	1	1
		Water Chemistry - Expanded	1	1.5	1	1	2	1	1	1	1	1	1
		Aquatic Macroinvertebrates	1	1	2	2	1	1	1	1	1	1	1
		Aquatic Periphyton	3	2.5	3	3	3	3	3	2	3	3	3
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	1	1.5	1	1	1	1	1	1	1	1	1
		Invasive/Exotic Plants, Animals and Diseases – Early Detection	1	2	1	1	1	1	2	1	1	1	1
	Focal Species or Communities	Shrubland Forest and Woodland Communities	1	1	1	1	3	3	1	2	1	1	1

			Tier Ranks (Final Network Rank, Workshop Rank, and Park Management Ranks)										
Level 1 Category	**Level 2 Category**	**Level 3 Category "Vital Sign"**	**Final Rank**	**Work Shop**	**ALPO**	**JOFL**	**FONE**	**FRHI**	**DEWA**	**UPDE**	**NERI**	**GARI**	**BLUE**
		Riparian Communities	1	1	2	1	1	1	2	2	2	2	2
		Birds - Riparian Communities	2	2	2	2	1	1	2	3	2	2	2
		Mammals – Riparian Communities	3	3	3	3	3	3	3	3	2	2	2
		Birds – Breeding Communities	1	1.5	1	2	2	2	3	3	1	1	1
		Terrestrial Invertebrates	2	2	3	3	3	3	3	3	2	2	2
		Freshwater Communities – Mussels**	.	.	.	.	.	.	.	.	.	.	.
		Freshwater Communities - Crayfish	3	3	3	3	3	3	3	3	2	2	2
		Freshwater Communities - Macrophytes	3	3	2	2	3	3	3	2	3	3	3
		Fish Communities - Streams	2	2	2	2	3	3	3	2	2	2	2
		Fish Communities - Rivers	2	1	3	3	3	3	2	1	2	2	2
		Amphibians and Reptiles – Vernal Pond Community	2	2	2	3	2	2	2	3	2	2	2
		Amphibians and Reptiles – Streamside Salamander Community	2	2	3	3	2	2	3	3	2	2	2
		Amphibians and Reptiles	2	2	3	2	2	2	3	3	1	1	1
	At-risk Biota	T&E Species & Communities - State	1	2	1	1	1	1	2	2	1	1	1
		T&E Species & Communities - Federal	1	2	1	1	1	1	1	1	1	1	1
Human use	Point-Source Human Effects	Bioaccumulation	3	2	3	3	3	3	2	3	3	3	3
	Visitor and Recreation Use	Visitor Use	2	3	3	3	3	3	1	2	2	2	2
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	1	1	1	1	2	2	1	1	2	2	2
		Landscape Pattern	1	1	2	2	2	2	1	2	2	2	2
	Energy Flow	Primary Production	3	3	3	3	3	3	3	3	3	3	3
	Nutrient Dynamics	Nutrient Dynamics	3	2	3	3	3	3	3	2	3	3	3

**The vital sign "Freshwater Communities – Mussels" was proposed to be added during the park management significance ranking process. It's status as a network vital sign and its rank are pending review by the ERMN SAC.

3.1.6. Network Summarization and Internal Review

Following the management significance ranking process, we used the computing and discerning power of the human brain to assimilate the workshop (ecological significance) and park (management significance) ranks. It was not possible to take any straight "averages" (although basic summary statistics such as mean, median, mode, counts, etc. were used – See appendix K – Prioritization Process) because not each ecosystem working group at the workshop ranked each vital sign and park managers ranked vital signs using two different ranking systems. As such, we took an overarching view of each rank and ranking system to assign the final network rank

(Table 3.1). In almost all cases the various ranking processes complimented and reinforced each other and most final tier-rank were obvious. Those cases in which it was not will be specifically addressed and resolved at the fall 2005 SAC meeting.

The final assimilation of ranks was the fifth major milestone in the vital signs selection and prioritization process.

3.2 Vital Signs for the Eastern Rivers and Mountains Network

While we recognize that all 36 vital signs are important, considered high priority (by definition), and warrant protocol development and implementation, the objective of assigning an overall priority rank ("implementation tiers") was to clearly specify which vital signs the network should move forward on protocol development first. Given financial and logistical realities it is imperative that we develop the *most* important elements in the program first. This notion (that a "tier-1" ranking carried substantial and significant weight for the future direction of the program) was verbalized repeatedly throughout the workshop and park ranking processes.

In keeping with the general idea of doing fewer things better, we propose (pending fall 2005 SAC and BOD review and approval) to begin protocol development on those vital signs assigned the tier -1 implementation category first. And then, as staffing and budgeting allow, move to tier -2 and -3 vital signs (Table 3.2). The network may collaborate with an existing national monitoring program(s) (e.g., for several of the air and climate vital signs). In several cases it may be possible to efficiently and cost-effectively incorporate several vital signs into a single protocol. In these cases lower tier vital signs may be incorporated sooner than their priority rank. And still other tier -2 and -3 vital signs may be elevated to more prompt protocol development based on SAC and BOD guidance. We will look for all possible efficiencies and collaborations within and outside the NPS to implement as many of the network vital signs as possible.

We present the list of vital signs for the Eastern Rivers and Mountains Network as they currently stand ready for review and discussion by the ERMN SAC and BOD in Table 3.2. The information contained therein is likely to change as the program develops.

Table 3.2. List of 36 Vital Signs for the Eastern Rivers and Mountains Network Parks including symbology for funding source and implementation priority.

Level 1 Category	Level 2 Category	Level 3 Category "Vital Sign"	Final Rank	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Air and Climate	Air Quality	Ozone	2	●	●	●	●	●	●	●	●	●
		Wet and Dry Deposition	1	●	●	●	●	●	●	●	●	●
	Weather and Climate	Weather and Climate	1	+	+	+	+	+	+	+	+	+
Geology and Soils	Geomorphology	Stream/River Channel Characteristics	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
	Soil Quality	Soil Erosion and Compaction	3	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Soil Function and Dynamics	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
Water	Hydrology	Surface Water Dynamics	1	+	+	+	+	● / +	● / +	● / +	● / +	● / +
		Wetland Water Dynamics	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Groundwater Dynamics	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
	Water Quality	Water Chemistry - Core	1	+	+	+	+	+	+	+	+	+
		Water Chemistry - Expanded	1	+	+	+	+	+	+	+	+	+
		Aquatic Macroinvertebrates	1	+	+	+	+	+	+	+	+	+
		Aquatic Periphyton	3	✧	✧	✧	✧	✧	✧	✧	✧	✧

Level 1 Category	Level 2 Category	Level 3 Category "Vital Sign"	Final Rank	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	1	+	+	+	+	+	+	+	+	+
		Invasive/Exotic Plants, Animals and Diseases – Early Detection	1	+	+	+	+	+	+	+	+	+
	Focal Species or Communities	Shrubland Forest and Woodland Communities	1	+	+	+	+	+	+	+	+	+
		Riparian Communities	1				+	+	+	+	+	+
		Birds - Riparian Communities	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Mammals – Riparian Communities	3	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Birds – Breeding Communities	1	+	+	+	+	+	+	+	+	+
		Terrestrial Invertebrates	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Freshwater Communities – Mussels	.					✧	✧	✧	✧	✧
		Freshwater Communities - Crayfish	3	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Freshwater Communities - Macrophytes	3					✧	✧	✧	✧	✧
		Fish Communities - Streams	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Fish Communities - Rivers	2					✧	✧	✧	✧	✧
		Amphibians and Reptiles – Vernal Pond Community	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Amphibians and Reptiles – Streamside Salamander Community	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
		Amphibians and Reptiles	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
	At-risk Biota	T&E Species & Communities - State	1	+	+	+	+	+	+	+	+	+
		T&E Species & Communities - Federal	1	+	+	+	+	+	+	+	+	+
Human use	Point-Source Human Effects	Bioaccumulation	3					✧	✧	✧	✧	✧
	Visitor and Recreation Use	Visitor Use	2	✧	✧	✧	✧	✧	✧	✧	✧	✧
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	1	+	+	+	+	+	+	+	+	+
		Landscape Pattern	1	+	+	+	+	+	+	+	+	+
	Energy Flow	Primary Production	3	✧	✧	✧	✧	✧	✧	✧	✧	✧
	Nutrient Dynamics	Nutrient Dynamics	3	✧	✧	✧	✧	✧	✧	✧	✧	✧

+ =Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
● = Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other monitoring efforts.
✧ = High-priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.
<blank> = Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

3.3 Relationship of the Proposed Vital Signs to Conceptual Models and Justifications

Each vital sign designated as a "tier -1" is linked to our general conceptual model (Figure 3.1) to demonstrate how this suite of vital signs meets the stated approach to monitoring (Section 1.2.3) to integrate elements of threat specific, ecosystem status, and focal resource monitoring.

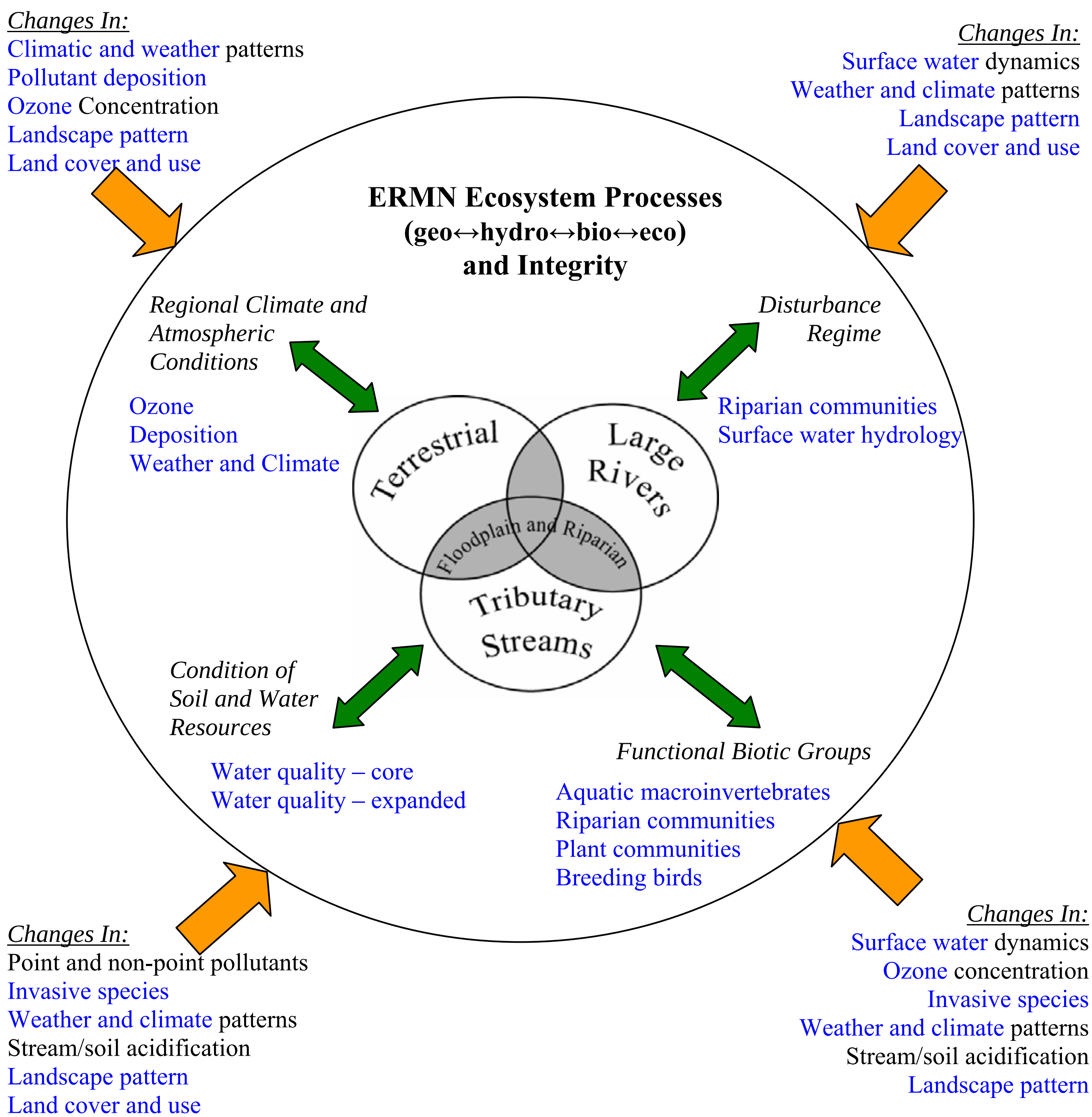


Figure 3.1. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (italicized), broad-scale ERMN ecosystem processes and integrity, and vital signs (blue text). Interactive controls must be conserved if ERMN ecosystems are to be maintained. Major changes (natural or anthropogenic) in any interactive control will result in a new ecosystem with distinctly different properties.

Chapter 11. Literature Cited

Abel, N., H. Ross, and P. Walker. 1998. Mental models in rangeland research, communication and management. Rangeland Journal **20**(1):77–91.

Barrett WG, VanDyne GM, Odum EP. 1976. Stress ecology. BioScience **26**: 192-194.

Chapin, F. S., III, M. S. Torn, and M. Tateno. 1996. Principles of ecosystem sustainability. The American Naturalist **148**: 1016-1037.

Croze, Harvey. 1982. Monitoring within and outside protected areas. Pages 628-633 *in* Jeffrey A. McNeely and Kenton R. Miller, eds. National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Proceedings of the World Congress on National Parks, October 11-22, 1982, Bali, Indonesia. Smithsonian Institution Press. Washington, D.C.

Davis, Gary E. 1989. Design of a long-term ecological monitoring program for Channel Islands National Park, California. Natural Areas Journal **9**(2): 80-89.

Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Oxford, UK.

Halvorson, Curtis H. 1984. Long-term monitoring of small vertebrates: a review with suggestions. Pages 11-25 *in* Janet L. Johnson, Jerry F. Franklin, and Richard G. Krebill, coordinators. Research Natural Areas: Baseline Monitoring and Management. Proceedings of a Symposium, March 21, 1984, Missoula, Montana. USFS General Technical Report INT 173. Forest Service Intermountain Forest and Range Experiment Station, Ogden, Utah. 84 pp.

Jenkins, K., A. Woodward, and E. Schreiner. 2002. A framework for long-term ecological monitoring in Olympic National Park: prototype for the coniferous forest biome. United States Geological Survey, Forest and Rangeland Ecosystem Science Center, Olympic Field Station, Port Angeles, WA.

Jenny, H. 1941. Factors of soil formation: a system of quantitative pedology. McGraw-Hill, New York, NY.

Jenny, H. 1980. The soil resource: origin and behavior. Springer-Verlag, New York, NY.

Johnson, W.C. and S.P. Bratton. 1978. Biological monitoring in UNESCO biosphere reserves with special reference to the Great Smoky Mountains National Park. Biological Conservation **13**:105-115.

Jones, K.B. 1986. The inventory and monitoring process. Pages 1-9 *in* A. Y. Cooperrider, R. J. Boyd, and H. R. Stewart, eds. Inventory and Monitoring of Wildlife Habitat. USDI Bureau of Land Management. Service Center. Denver, Colorado. 858 pp.

Karr, J.R. 1991. Biological integrity: a long neglected aspect of water resources management. Ecological Applications **1**:66-84.

Karr, J. R. 1999. Defining and measuring river health. Freshwater Biology **41**: 221-234.

Limburg, K.E., O'Neill R.V., Costanza R., and S. Farber. 2002. Complex systems and valuation. Ecological Economics **41**:409-420.

Mahan, C.G. 2004. A Natural Resource Assessment for New River Gorge National River. Natural Resource Report NPA/NERCHAL/NRR-04/006. U.S. Department of Interior, National Park Service, Northeast Region, Philadelphia, PA.

Michener, William K. and James W. Brunt. 2000. Ecological Data Design, Management, and 43 Processing. Blackwell Scientific Ltd., London.

National Park Service. 1916. Organic Act.

National Park Service. 1982a. General management plan. Fort Necessity National Battlefield.

National Park Service. 1982b. General management plan. Friendship Hill National Historic Site.

National Park Service. 1993. Resource management plan. New River Gorge National River, Gauley River National Recreation Area and Bluestone National Scenic River.

National Parks Omnibus Management Act of 1998.

National Park Service. 1998. Resources management plan. Allegheny Portage Railroad National Historic Site /Johnstown Flood National Memorial.

National Park Service. 1999. Strategic plan. Delaware Water Gap National Recreation Area.

National Park Service. 2000. Resources management plan (Draft). Upper Delaware Scenic and Recreational River.

National Park Service. 2001. 2001 NPS Management Policies. National Park Service, Washington, D.C. Online. (http://www.nps.gov/refdesk/mp/).

National Park Service. 2002a. Resource management plan. Delaware Water Gap National Recreation Area.

National Park Service. 2002b. Natural Resource Planning Assistance. Fort Necessity National Battlefield.

National Park Service. 2002c. Natural resource planning assistance. Friendship Hill National Historic Site.

Noon, B.R. 2003. Conceptual issues in monitoring ecological systems. Pp. 27-72 In: Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. D.E. Busch and J.C. Trexler, eds. Island Press.

Purvis, Jesse M. 2002. Water resources management plan, New River Gorge National River, Gauley River National Recreation Area, Bluestone National Scenic River, West Virginia. Glen Jean, WV: U. S. Department of the Interior, National Park Service; 234 p.

Quinn, J.F. and C. van Riper III. 1990. Design considerations for national park inventory databases. Pages 5-14 *in* Charles van Riper III, Thomas J. Stohlgren, Stephen D. Veirs, Jr., and Silvia Castillo Hillyer, eds. Examples of Resource Inventory and Monitoring in National Parks of California. Proceedings of the Third Biennial Conference on Research in California's National Parks, September 13-15, 1990, University of California, Davis, California. 268 pp.

Roman, C.T., and N.E. Barrett. 1999. Conceptual framework for the development of long-term monitoring protocols at Cape Cod National Seashore. USGS-Patuxent Wildlife Research Center. 68 pp.

Starfield, A.M. 1997. A pragmatic approach to modeling for wildlife management. Journal of Wildlife Management **61**:261–270.

Scheffer M., Carpenter S., Foley J.A.,Folke C., and B. Walker. 2001. Catastrophic shifts in ecosystems. Nature **413**:591-596.

Thomas, L. 2001. Conceptual models: What are they and how do we use them to design monitoring programs? Presentation to the Vital Signs Monitoring Meeting, Phoenix, AZ, August 20–24, 2002. National Park Service.

White, P.S. and S.P. Bratton. 1980. After preservation: philosophical and practical problems of change. *Biological Conservation* **18**:241-255.

Wiersma, G.B. 1984. Integrated global background monitoring network. Presented at Symposium: Research and Monitoring in Circumpolar Biosphere Reserves. Waterton Biosphere Reserve, Waterton Lakes, Alberta, Canada, August 27-31.

Woodley, S. 1993. Monitoring and measuring ecosystem integrity in Canadian National Parks pp. 155-175 *in* S. Woodley, J. Kay, and G. Francis, editors. Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Delray Beach, FL.

Woodward, A., K. J. Jenkins and E. G. Schreiner. 1999. The role of ecological theory in long term ecological monitoring: report of a workshop. Natural Areas Journal **19**: 223-233.

GLOSSARY

Adaptive management - systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form-"active" adaptive management-employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

Adaptive monitoring design – an iterative process that refines the specifications for monitoring over time as a result of experience in implementing a monitoring program, assessing results, and interacting with users.

Attributes - any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. See Indicator.

Disturbance - any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment. In relation to monitoring, disturbances are considered to be ecological factors that are within the evolutionary history of the ecosystem (e.g., drought). These are differentiated from anthropogenic factors (see *stressors,* below) that are outside the range of disturbances naturally experienced by the ecosystem.

Driver – a natural agent responsible for causing temporal changes or variability in quantitative measures of structural and functional attributes of ecosystems. See *Ecosystem drivers.*

Ecological indicator – see *indicator*.

Ecological integrity - a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecological sustainability – the tendency of a system or process to be maintained or preserved over time without loss or decline.

Ecosystem – a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries.

Ecosystem drivers - major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. See *Driver*.

Ecosystem health – a metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem sustainability and ecological integrity.

Ecosystem management - the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

Focal resources - park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Focal species / organisms – species / organisms that play significant functional roles in ecological systems by their disproportionate contribution to the transfer of matter and energy, by structuring the environment and creating opportunities for additional species / organisms, or by exercising control over competitive dominants and thereby promoting increased biological diversity.

Indicators - subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

Measures - the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Resilience – the capacity of a particular ecological attribute or process to recover to its former reference state or dynamic after exposure to a temporary disturbance and/or stressor. Resilience is a dynamic property that varies in relation to environmental conditions.

Resistance – the capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state or dynamic despite exposure to a disturbance and/or stressor. Resistance is a dynamic property that varies in relation to environmental conditions.

Stressors - physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level. Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).